



# Recommendations Emerging from an Analysis of NASA's Deep Space Communications Capacity

Douglas S. Abraham, Bruce E. MacNeal, David P. Heckman, Yijiang Chen, Janet P. Wu, Kristy Tran, Andrew Kwok, and Carlyn-Ann Lee

Jet Propulsion Laboratory, California Institute of Technology

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# Background



- 2016: NASA's Space Communications and Navigation (SCaN) Office chartered a "Deep Space Capacity Study."
- Purpose: To provide a basis for formulating a deep space communications and navigation investment strategy.



## Pass-1 (Fall 2016)

- 30-year capacity demand projection
- Identification and analysis of supply shortfalls
- Initial concepts for eliminating shortfalls



## Pass-2 (Spring 2017)

- Seek more cost-effective concepts for eliminating capacity shortfalls
- "Flesh out" the most promising concepts

# Projecting Future Mission Needs



Mission set analysis involves the coordinated application of a suite of specialized tools.

**Space Communications Mission Model (SCMM)**

Agreed Upon Mission Set Between HQ, JPL, & GSFC. High-level Mission Characteristics

Mission Set Scenarios

**(MSAT)**

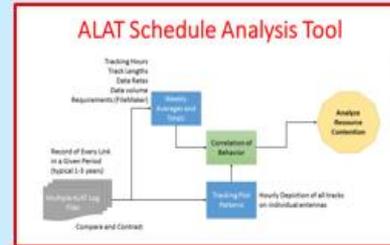
Detailed Mission & Spacecraft Characteristics; RF Link Analyses

**Mission Set Analysis Tool**

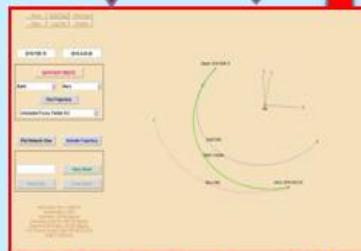
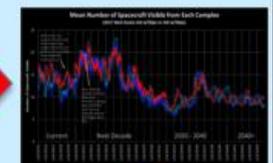
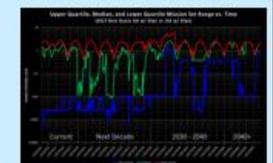
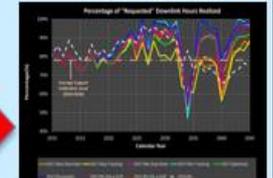
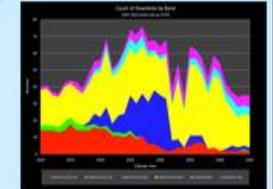
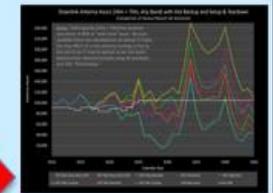
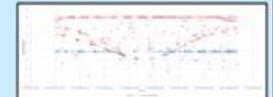
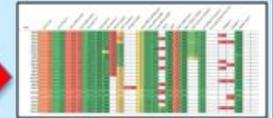
Requirements Analysis	Tabular Report	Comm Link Output*	DDN Sim Output
Gen ACCESS	Timing of Op Segs	Mission Drivers	ArchTool Output
Change Key Name	Mission Status	Comm Band Composition	Cost Profile
	Counting UL, DL Missions, SC	Names and Aliases*	Days in Year
	Track Hrs Hists	Track Time	Data Volume
	SCMM Comparison	BandWidth	Sep. N12 Check

**(ASAT)**

Analyzes simulated schedule output from ALAT to understand underlying resource contention drivers



Aggregate Mission Set Trends & Requirements



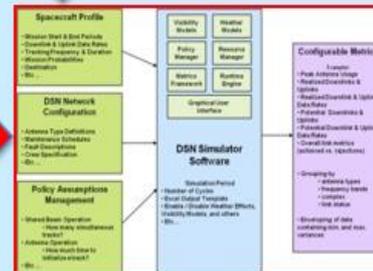
**Orbital Trajectory Inference Engine (OTIE)**

Spacecraft Range Distance, Geometry, and Visibility Relative to Ground Stations as a Function of Time



**Strategic Optical Link Tool (SOLT)**

Optical Link Parameters / High-Level Link Performance as a Function of Time



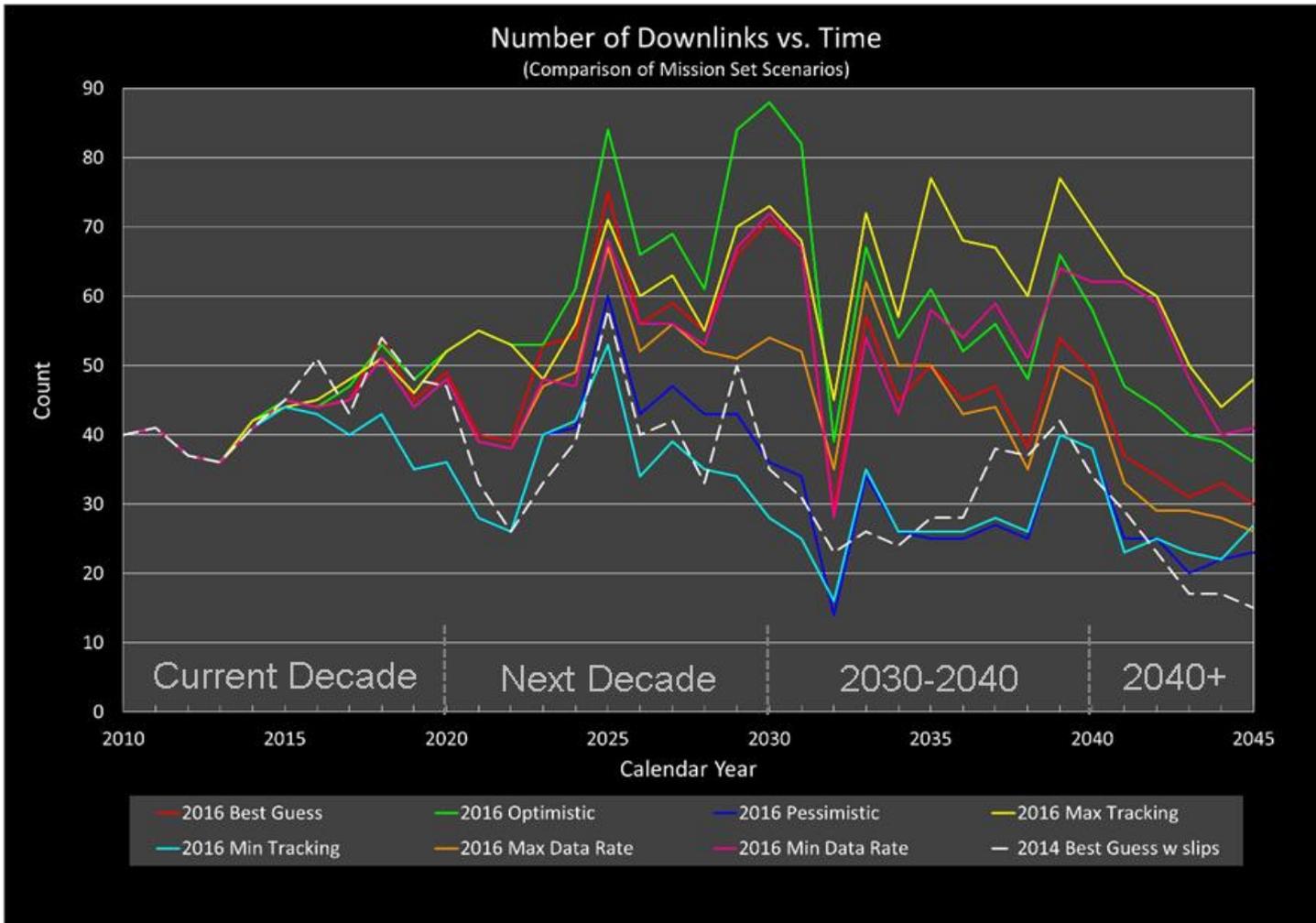
**Architecture Loading Analysis Tool (ALAT)**

Antenna/Telescope Architecture Loading Simulations

Architecture Loading & Data Traffic Implications

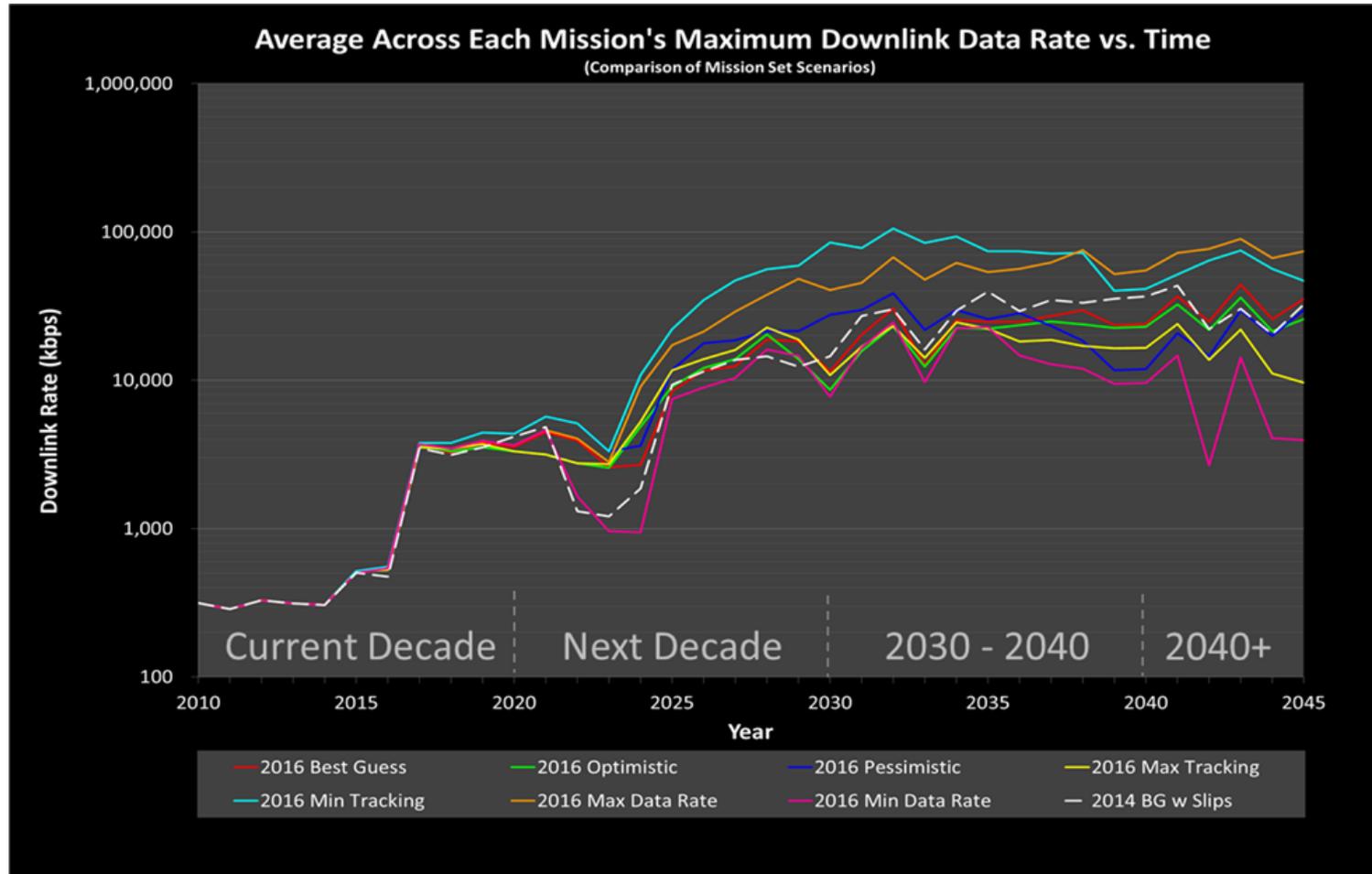
Aggregate & Individual Mission Geometry as a Function of Time

# Key Trends (1/4)



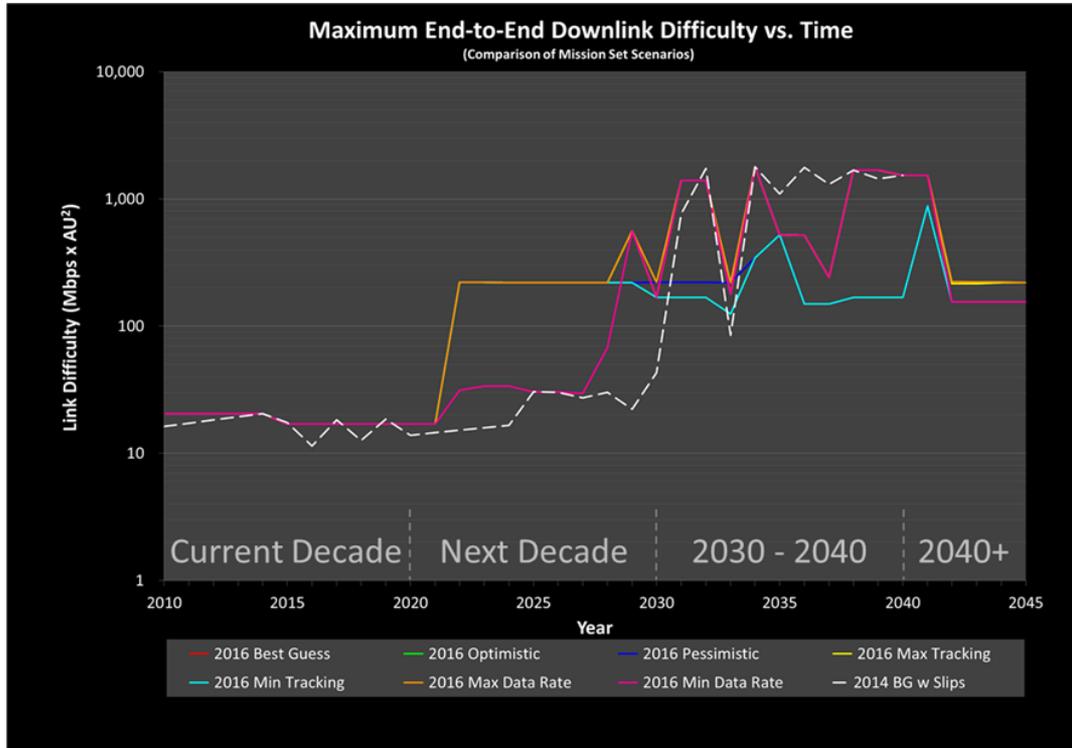
In most scenarios, the number of downlinks (and associated spacecraft) increase dramatically in the next decade.

# Key Trends (2/4)



Average data rates increase significantly over the next decade, leveling off as link difficulties and RF bandwidth allocation constraints become formidable.

# Key Trends (3/4)



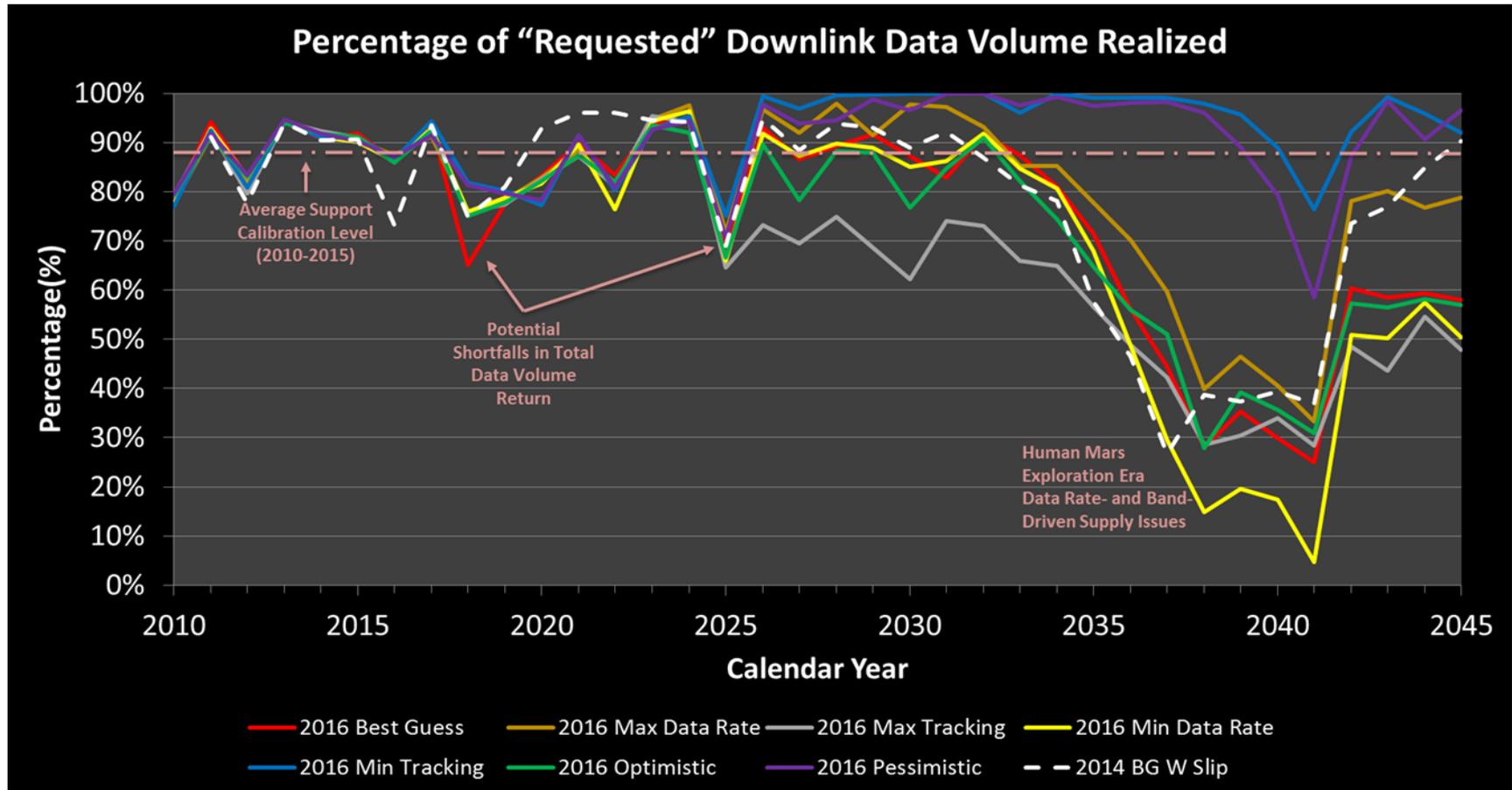
High data rates at long link distances drive large end-to-end link difficulties.

At RF, this necessitates arraying antennas which “eats” into available capacity.

	Range from Earth (AU)	Number of 34m Antennas
Mars Average (Time-based)	1.71	2.89 -> 3; plus 1 “hot” backup
Max Mars (50 yrs)	2.66	6; plus 1 “hot” backup
Min Mars (50 yrs)	0.38	0.14 -> 1; plus 1 “hot” backup

Number of 34m antennas needed to close link with a Mars Areostationary Relay satellite transmitting at 250 Mbps via a 500W transmitter and a 6m HGA

# Key Trends (4/4)



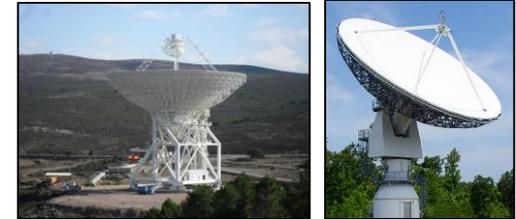
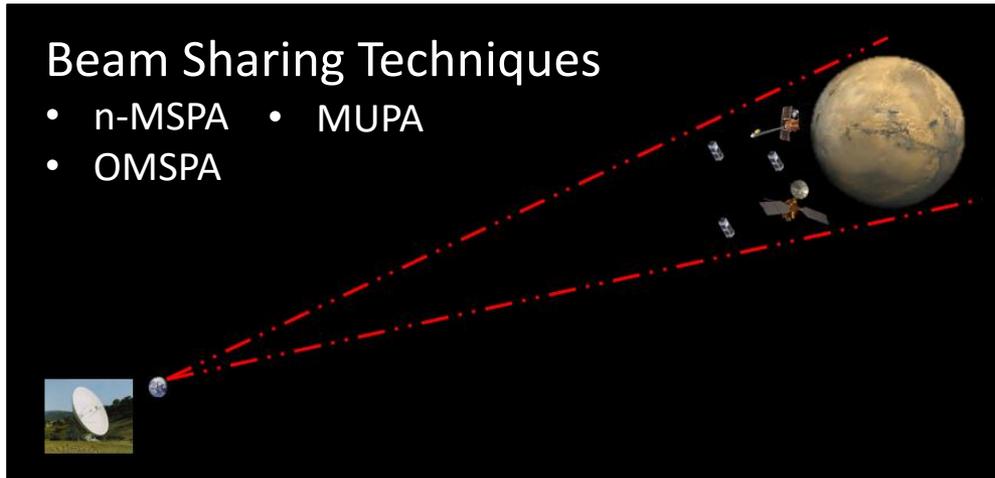
Loading simulations show asset contention in the 2020s and major capacity shortfalls beginning in the 2030s – when the more demanding individual links require more arrayed antennas than are available at a given Complex.

# Addressing the Shortfalls (1/5)

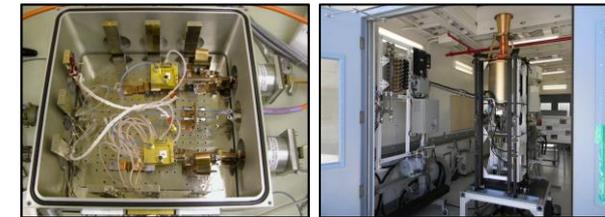


## Pass-1 Solutions

- For Asset Contention in the 2020's:

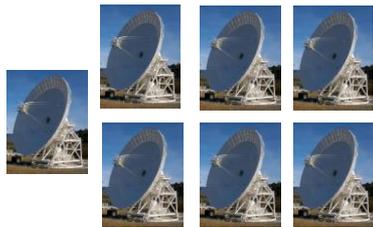


International and University Cross-Support



Adding Additional Frequency Band Capabilities on Existing Antennas

- For Asset Contention in the 2030's and beyond:



+ **2020 Pass-1 Measures**

7 New 34m BWGs Per Complex Operating as an Array

or



3 New 34m BWGs Per Complex Operating as an Array (esp. for uplink)

+

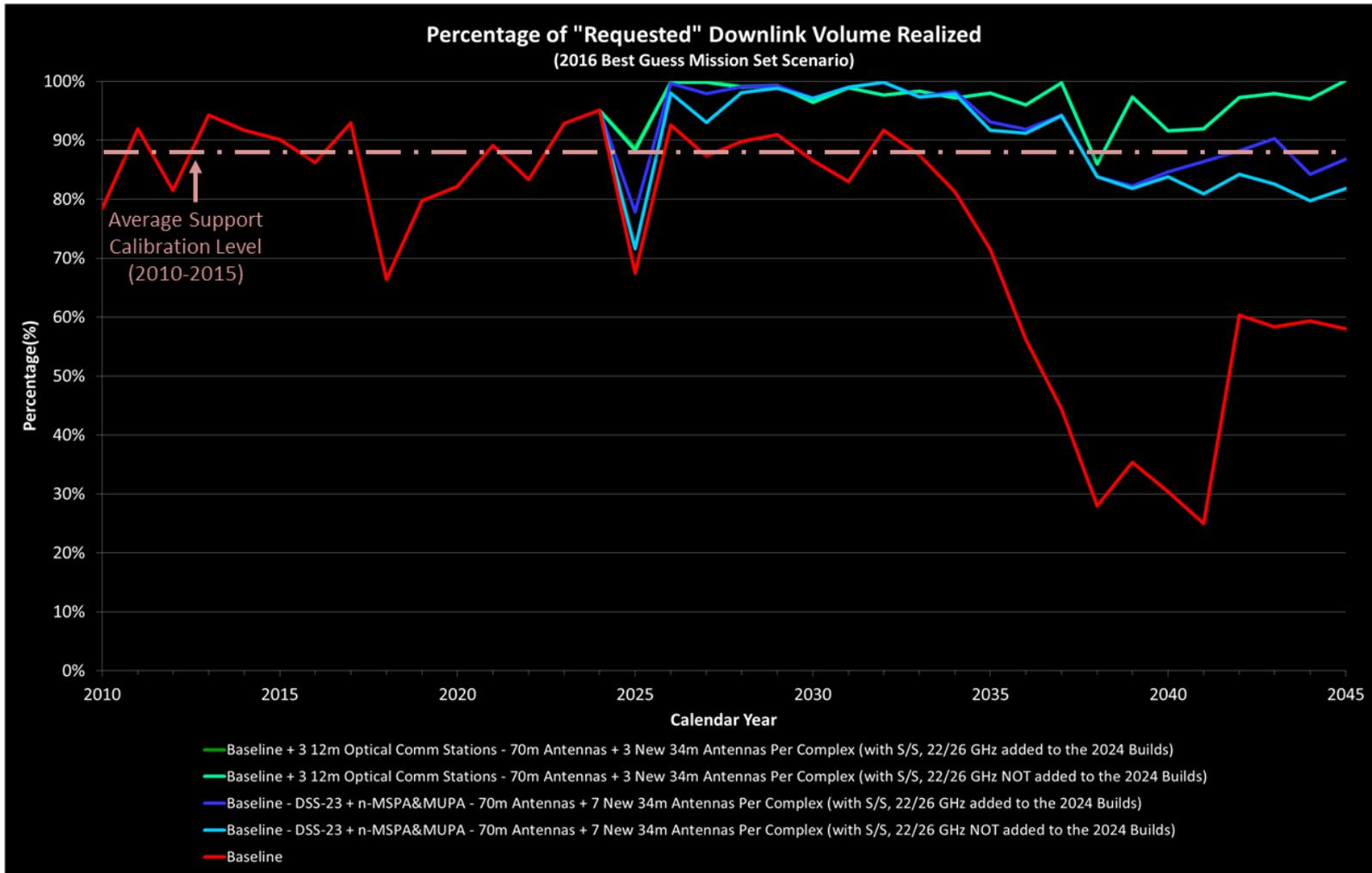


1 New 12m Optical Ground Station

+

**2020 Pass-1 Measures**

# Addressing the Shortfalls (2/5)



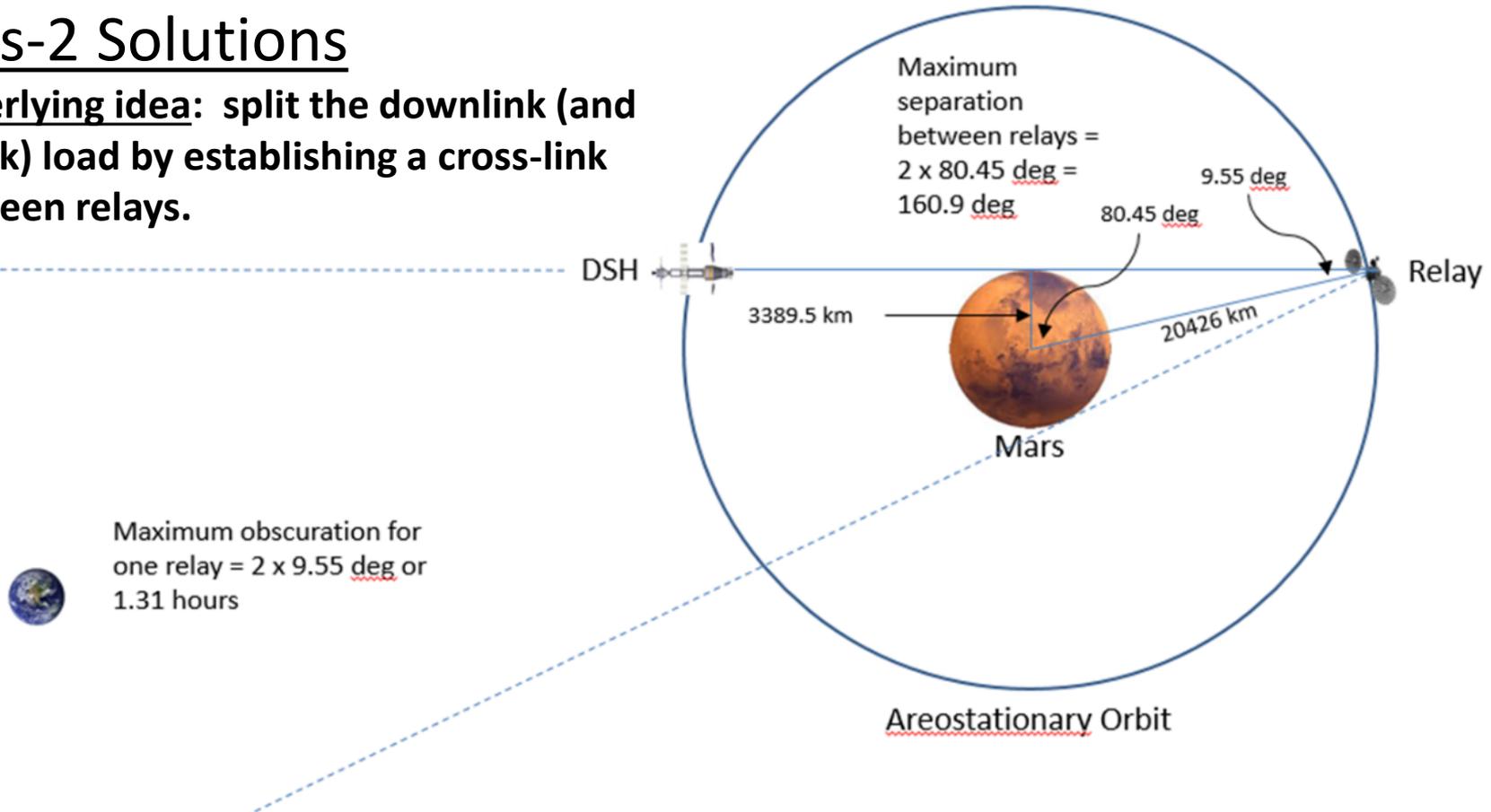
Either the RF or Combined RF-Optical approaches satisfied most of the downlink volume demand – though, the RF-Optical performed the best.

# Addressing the Shortfalls (3/5)



## Pass-2 Solutions

Underlying idea: split the downlink (and uplink) load by establishing a cross-link between relays.



A cross-link between the two areostationary relays allows “dual-trunk links” to send back the same total volume of data at half the data rate – hence, requiring half the G/T on the ground, provided both trunk links are MSPA’d.

# Addressing the Shortfalls (4/5)

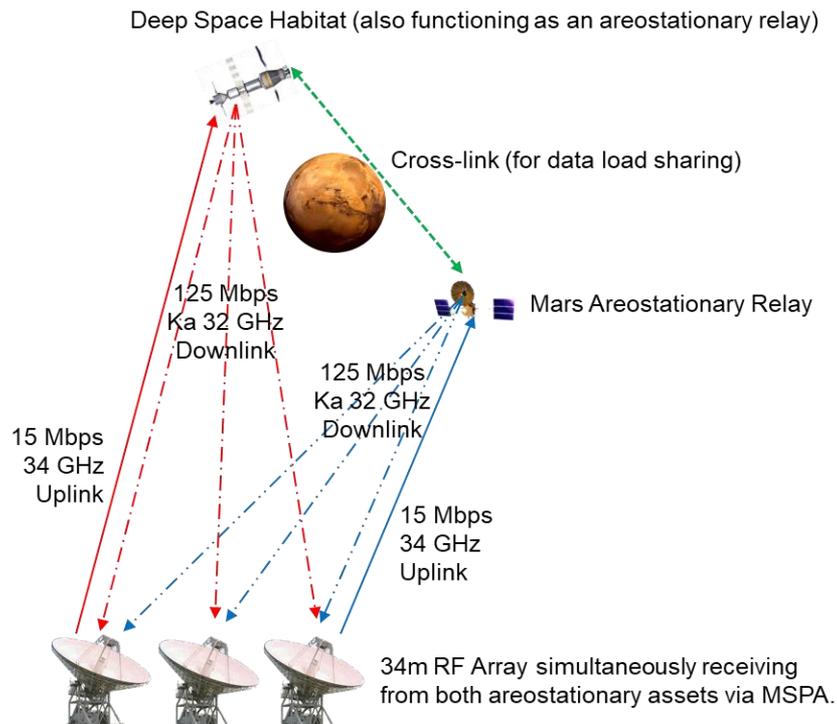


## Pass-2 Solutions

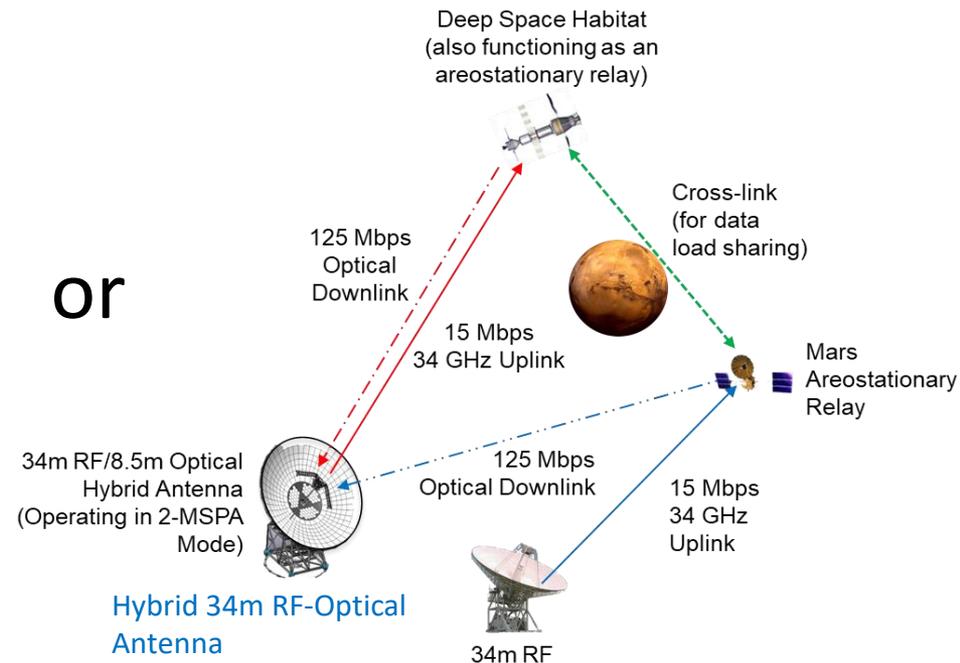
- For Asset Contention in the 2020's: Same as for Pass-1

- For Shortfalls in the 2030's and Beyond:

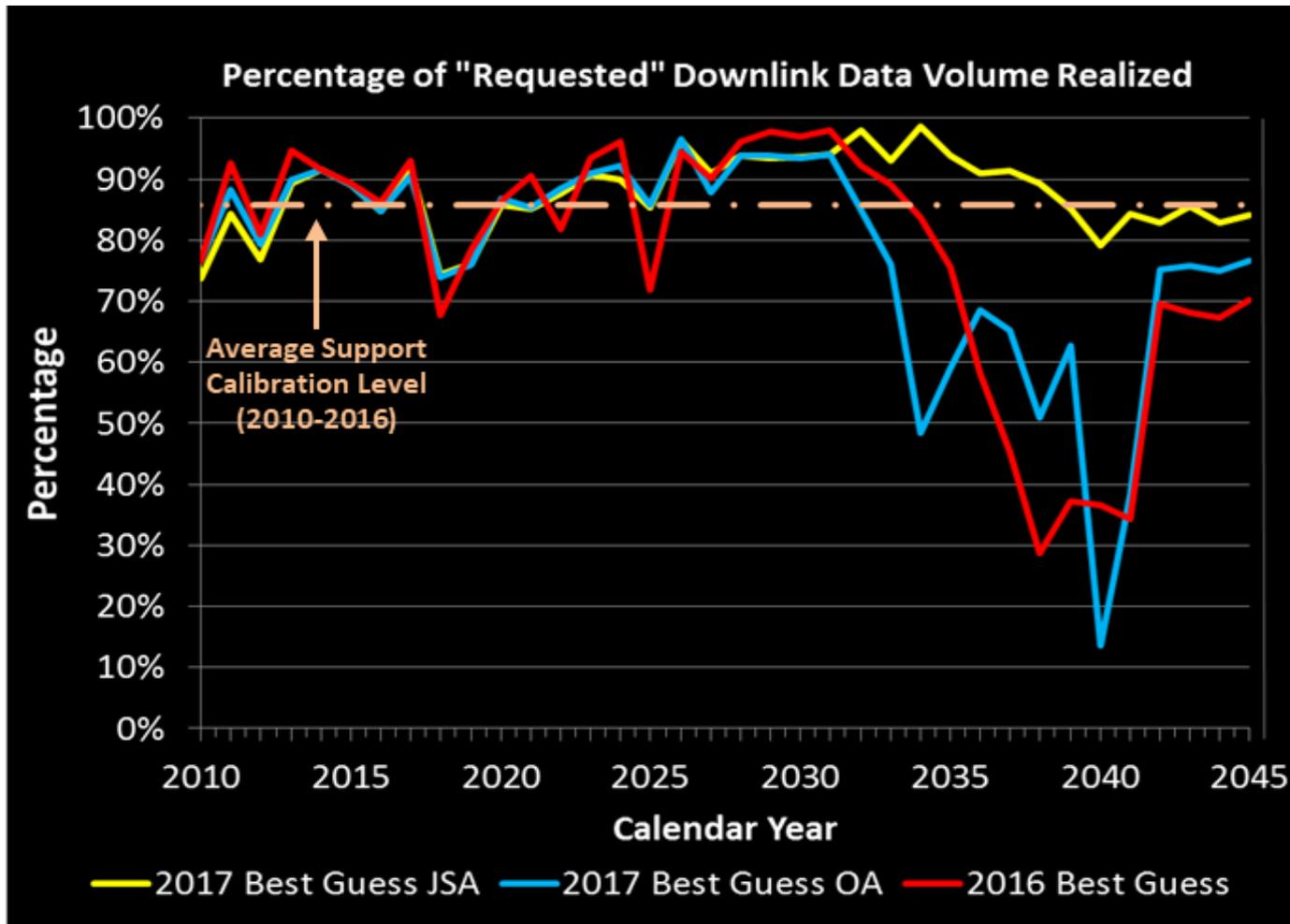
For details see Wallace Tai's "Mars Planetary Network for Human Exploration Era"



or



# Addressing the Shortfalls (5/5)



“2017 Best Guess JSA” embodies the Pass-2 solutions – aggregate mission set requirements are satisfied.

# Recommendations



- Driver: Steep increase in number of spacecraft requiring DSN support in next 10 years
  - Develop and maximize use of beam sharing (n-MSPA, OMSPA, MUPA).
  - Add additional bands (e.g., 22/26 GHz) to some existing antennas to achieve greater scheduling flexibility.
  - Foster international and university cross-support.
- Driver: Steep increase in data rates over next 10 years
  - Develop ability to array up antennas at Ka-band to close RF links.
  - Develop optical communications capability (e.g., RF-optical hybrids antennas) to ease RF antenna demand and circumvent allocated-RF-spectrum constraints.
- Driver: Beyond 2030, human exploration drives data rates on trunk link to/from Earth.
  - Develop cross-links for use between relays to load-share and use dual-trunk links back to Earth to keep required data rates at manageable levels.
- Doing all of the above takes a long time. Start now.